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AN EXPERIMENTAL INVESTIGATION OF AN ELLIPTICAL RISERS FLAT-PLATE COLLECTOR USING COILS INSERT

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ABSTRACT

A flat-plate solar collector system is investigated with five elliptical risers that utilized for heating the water. Two solar collectors are used with and without coil inserts. Four elliptical coils are used as inserts for each risers of the heat solar collector. The two heat collectors are operated during the periods from 3rd to 5th January2019 of winter season with constant tilted angle of 54oat sunny weather in Baghdad city (33.3oN and 44.3oE). The experimental results indicate that the solar collector system with elliptical coils inserts gave the best performance in term of outlet temperature about 13% more than that solar collector without inserts. Also, the efficiency of solar collector with coil inserts increased about 20% than that solar collector without inserts. The present results are compared with previous work and a good convergence in behavior is noticed.

KEYWORDS: Flat-Plate Collector, Elliptical Risers, Experimental Investigation & Coils Insert

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Original Article

1. INTRODUCTION

The renewable energy is a source of uninterruptible power and continuously renew such as water, sun, wind, chemical reaction, biomass products, coal, natural gas and many of nature components can consider as renewable energy sources. Many countries interested in using the renewable energy at different dominate applications, several studies for enhancing solar systems such as reducing the waste heat [1] are done in order to reduce the fuel consumption. The flat-plate solar collector is one of the common types of solar collector systems that convert the radiant solar energy from the sun into heat energy using flat-plate absorber. The main advantages of using flat plate collectors are the simple constriction, easily manufacturing and high thermal efficiency.

Myrna Dayan [2], studied the performance of solar collector at low flow rate of water to increase tank stratification, less costly and increasing in useful energy. He noticed the thermal performance of solar collector is influenced by any small aberration from the optimum flow rate while in high water flow rate the performance is insensitive. He concluded the amount of flow rate depend on the temperature difference value.

H. M. S. Hussein et al. [3], experimentally presented the performance of heat pipe solar collectors with different cross sections geometries of pipes. They found that the elliptical heat pipe efficient more than a circular pipe at low filling ratios.

K. Sivakumar et al. [4], experimentally and theoretically studied the thermal performance of flat-plate solar collector with elliptical pipe. They computed the collector efficiency and outlet temperatures of condenser and heat pipe with the modification. They found the outlet temperature though the same flow trend is very low comparing with heat pipe temperature, also they show the big losses through heat exchange between the working

fluid and the water.

Braa Khalid Ameen et al. [5], tested the enhancement of heat transfer for flat-plate solar collector in Iraq climatic conditions using three different cases, namely using three types of inserts, using different material of absorber, copper and aluminium materials and using collector with glazing and other without. As a comparison between these methods. They noticed that the double twisted tape insertion gave higher outlet temperature than those other types of inserts. Also, they found the temperature of the copper absorber increased about 6 oC than the aluminium absorber and the collector with a glass sheet increase about 4 oC in temperature as compared with collector without glass sheet.

Jafar Mehdi et al. [6], simulated the enhancement techniques of solar water collectors with flat-plate with laminar flow. They noticed that the useful energy of solar collector with inserts is enhanced about 10% higher than the collector without inserts.

S. N. Shehab [7], experimentally investigated a steady state natural heat convective inside a heated externally open end circular-section tube with and without ring inserts for different aspect ratios. He noticed the heat performance improved for tube with ring inserts about 25% larger than that tube without ring inserts.

Ganesh K. et al. [8], analyzed the performance of flat-plate collector changing geometry of absorber tube. They conclude that the flat plate solar collector with semicircular pipes has amount of heat transfer more than the solar collector with circular pipes and when the flowing flow rate increase, the heat transfer to the fluid increase. Also, they found the decreasing in area of plate and length of header pipe and increasing in the pipe diameter lead to increasing in efficiency of the collector.

Rohit Khargotra et al. [9], studied the performance of a solar heater system and they compared different types of turbulator. They found that the rate of heat transfer increases from 18% to 70 % and increased in the maximum performance value about 70% up to the plain heater with the same conditions.

The present work focuses on the sun heat energy and the method of used it for heating water using coils insert enhancement to achieve the optimum operation. The aim of present work is to introduce experiment investigation for the flat-plate solar collector to improve the solar collector efficiency by using elliptic pipes with a new configuration of an elliptic coil inserts that inserts into the constant tilted angle of 54o at the south direction in Baghdad city at winter season.

2. EXPERIMENTAL SETUP

The experiment setup is designed and manufactured to cover the experiments of the present work as shown in figure (1). Two elliptical pipes solar collector are used, without and with four elliptical coils inserts for each pipe of collector. The setup is consist of flat-plate absorber, glazing sheets, wooding frame and storage tanks.

The flat-plates Absorber is manufactured from copper material with dimensionsof1500mm length, 900mm width and 1mm thickness. It is welded by copper taps with five elliptical riser pipes with length of 1600mm, 28mm major diameter, 14mm minor diameter (constant elliptical section aspect ratio of 2) and 1mm thickness as shown in figure (2), and insulated using fiber-glass with thickness of 50mm at the lower surface. Each riser pipes contain of 4 elliptical spring inserts (100mm length, 10 mm pitch and 1mm spring wire diameter) are distributed equally spaces into each pipes, and there attached with the inner wall of riser pipes. The upper surface of the absorber is painted with black color and covered by two glasses sheets. The riser pipes are joined with two copper headers with dimensions of 1350mm length, 54mm

diameter and 2mm thickness. The dimensions of lower glass sheet are 1800mm length, 1300mm width and 6mm thickness, and 2000 mm length, 1500mm width and 6 mm thickness for the upper glass. They are putted above the flat-plate with 20 mm gap between them inside the wooden box. The glazing sheets works on segregate the plate from surrounding ambient.

The wooden rectangular frame is surrounded the collector components. The wooden boxare2000 mm length, 1500mm width and 100 mm thickness. It is opened from the top side and the two glazing side to allow the sun radiations entering to the collector. The collector components are put inside the wooden box and it a good insulated.

Two cylindrical tanks made of klvenize steel material with dimensions of 500mm length, 250mm diameter and 1mm thickness, the first is the storage tank which is joint to the solar collector directly by the connecting tubes and the second is a support tank which is joint to the first tank. The advantages of the klvenaiz steel material are low conductivity and high corrosion resistance. The two tanks are putted in vertical position.

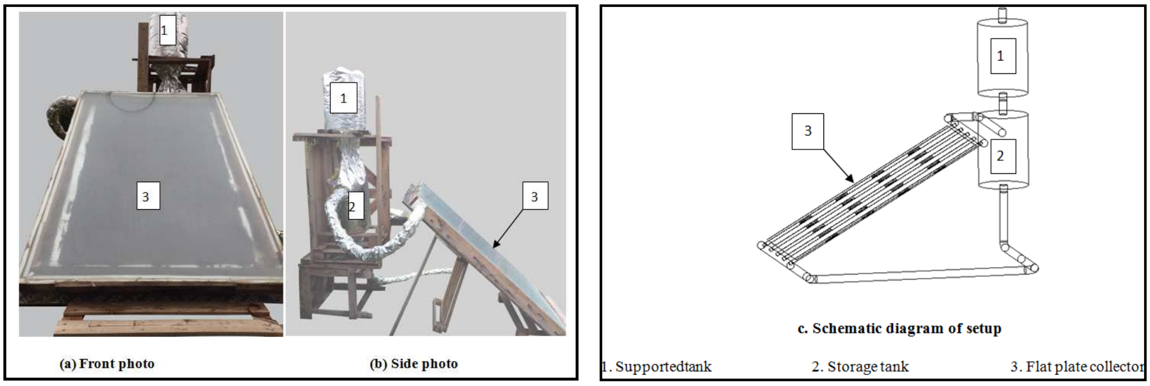

Figure 1: Photos and Schematic Diagram of Setup

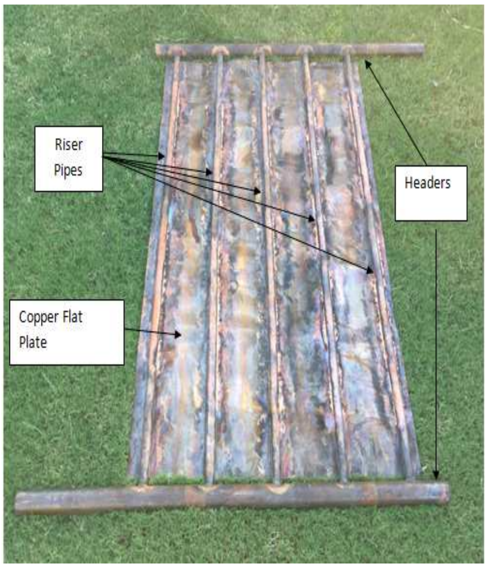

Figure 2: Risers Pipes with Headers and Absorber (Collector Components) Assembly

3. TESTS METHODOLOGY AND COMPUTATIONS

The experiment work is done by fixed inclination angle of 54° for south direction in Baghdad city from 3rd to 5thJanuary 2019 in the day time from 7:00am to 4:00 pm. The results are obtained for each hour is to compute the performance and instantaneous collector efficiency.

3.1 Heat Transfer Coefficient between Absorber and Glazing Covers

The convection and radiation heat transfer coefficients between absorber plate and glass cover1 are calculated as (Duffie and Beckman) [10]:

$$Hr_{p-c1} = \frac{\sigma(Tp^2 - Tc1^2)(Tp - Tc1)}{\frac{1}{\varepsilon p} + \frac{1}{\varepsilon c1} - 1} \tag{1}$$

$$H_{p-c1} = 1.14\,\frac{\Delta T^{0.31}}{L^{0.07}}[1\text{-}0.0018(\overline{T}\text{-}10)] \tag{2}$$

and the heat transfer coefficient between glass covers 1 and 2 is computed as follows [10]:

$$Hr_{c1-c2} = \frac{\sigma(Tc1^2 - Tc2^2)(Tc1 - Tc2)}{\frac{1}{\varepsilon c1} + \frac{1}{\varepsilon c2} - 1} \tag{3}$$

$$H_{c1-c2} = 1.14\,\frac{\Delta T^{0.31}}{L^{0.07}}[1\text{-}0.0018(\overline{T}\text{-}10)] \tag{4}$$

3.2 Heat Transfer Coefficient from Glass Cover 2 to Ambient

The convection and wind heat transfer coefficients between glasses cover 2 and ambient calculated as [10]:

$$Hr_{c2-a} = \varepsilon_c \sigma({T_{c2}}^2 - {T_a}^2)(T_{c2} - T_a) \tag{5}$$

$$H_w = 10.45 - v + 10\sqrt{v} \tag{6}$$

3.3 Overall Losses Coefficient

The overall losses coefficient (U_t) from absorber plate to the surrounding is computed from the sum of the heat transfer coefficients as follows[10]:

$$U_t = \left(\frac{1}{h_{p-c1} + hr_{p-c1}} + \frac{1}{h_{c1-c2} + hr_{c1-c2}} + \frac{1}{hr_{c2-a} + h_w}\right)^{-1} \tag{7}$$

3.4 Solar Collector Efficiency

The thermal collector efficiency (η) is calculated as follows [10]:

$$\eta = \frac{Q_u}{A_c \times I_t} \tag{8}$$

where,

The heat gained (Qu) by solar collector influenced by the removal factor and by absorbed solar radiation. The heat gain plays an important factor in efficiency value because when the heat gain increases the collector efficiency increases, and computed as follows [10]:

$$Q_u = A_c \times F_R[S - U_l(T_{f,i} - T_a)] \tag{9}$$

The heat removal factor (F_R) of the solar collector depends on the amount of mass flow rate and calculated as [10]:

$$F_R = \frac{\dot{m}C_p}{A_c U_l}\left(1 - e^{-\left(\frac{A_c . U_l . F'}{m' . C_p}\right)}\right) \tag{10}$$

The amount of absorbed solar radiation(S) from the sun heat energy by the absorber plate is evaluated as follows [10]:

S= beam radiation + diffuse sky radiation+ diffuse ground – reflected radiation

$$S= G_{bT}.(\tau\alpha)_b + (\tau\alpha)_d.(G_{dT} + G_{rT}) \quad (11)$$

Finally, the collector efficiency factor (F′)of the solar system is,

$$F' = \frac{\frac{1}{U_l}}{w\left[\frac{1}{U_l[D+(w-D)F]}+\frac{1}{c_b}+\frac{1}{\pi D_i h_{f,i}}\right]} \quad (12)$$

4. RESULTS AND DISCUSSIONS

The experimental results are represented in the graphs below. The effect of inlet, outlet temperatures and solar radiations on the thermal performance of heat solar collector are analyzed and investigated for different cases with and without inserts at winter season. A validation between the present work and previous work for outlet water temperature and ambient temperature with time of day in the winter season, under same design and approximate conditions is done as shown.

Figure (3) shows the behavior of outlet temperature versus day time for solar collectors with and without inserts. Using of inserts inside the riser pipes play an important rule on increasing the outlet temperature of the collector because of Reynolds number increase by the effect of small vortices which are created by the influent of insert on the water path.

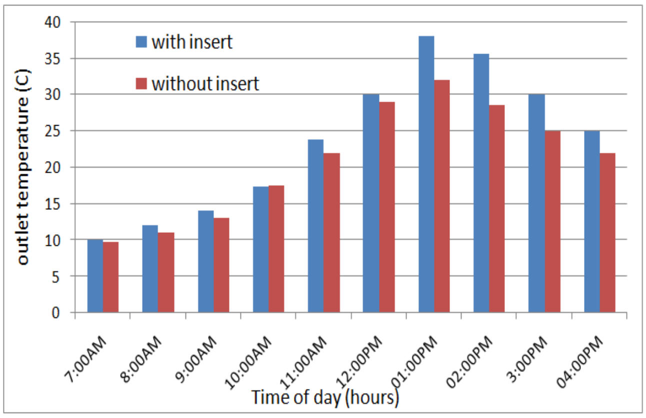

Figure 3: The Outlet Temperatures Versus Day Time for Elliptical Pipes Solar Collector With and Without Coil Inserts

Figure (4) shows the instantaneous solar collector efficiency and conclude that experimental efficiency for solar collector without inserts is less about (11.7%) than efficiency of solar collector with inserts at the same heat flux because of the elliptical coil effects on the outlet temperature which cause's high mass flow rate for water flow.

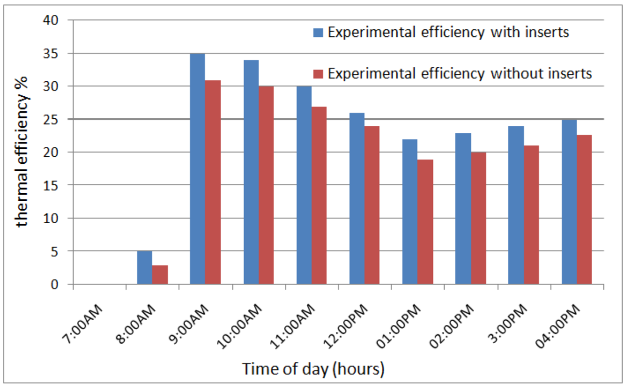

Figure 4: The Experimental Efficiency Versus Day Time for Elliptical Pipes Solar Collector With and Without Coil Inserts

The validation is done between the results of present work and Jamal H. [11] work as shown in figure (5) to validate the results of outlet water temperature and ambient temperature with time of day for winter season and a good convergence in behavior is noticed. The difference in water temperature between the two works because the difference in operation region.

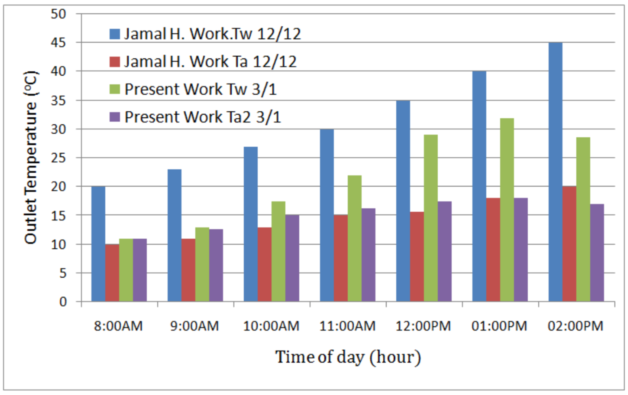

Figure 5: Comparison of Present Work for Solar Collector Without Inserts with Jamal H. Work [9]

5. CONCLUSIONS

In the present work, a new design of flat-plate solar collector is manufactured and designed in Baghdad-Iraq for winter season at constant tilted angle of 54°C. In this design five elliptical pipes with elliptical coil inserts and without inserts used. The main conclusions can be drawn as follows:

The experimental results indicate that the solar collector system with elliptical coil inserts gives outlet temperatures about 13% more than that solar collector without inserts.

The maximum outlet temperatures of water reach to 38°C for an elliptic pipe solar collector with elliptical coil inserts, and this enables the flat-plate collector to supply domestic hot water.

The solar collector with elliptical coil inserts produce about 10 to 12 lit/ hour of hot water at 38°C.

The thermal efficiency of solar collector with elliptical coil inserts increased about 20% than that solar collector without inserts.

Nomenclature

A_c	collector surface area, (m2).
C_b	bond conductance.
C_p	water specific heat =4.186, (KJ/Kg. K).,
G_{bT}	intensity of beam radiation, (W/m2).
G_{dT}	intensity of diffuse radiation, (W/m2).
G_{rT}	intensity of reflected radiation, (W/m2).
h_w	wind heat transfer coefficient, (W/ m2. K).
I_t	total radiation on a tilted surface, (W/m2).
K_b	bond thermal conductivity, (W/m. c).
$\overline{T}$	average temperature = (Tp +Tc /2), (oC).
U_t	coefficient of heat losses from the top side of the collector, (W/ m2K).
b	bond width, (mm).
H	heat transfer coefficient by convection, (W/ m2. K).
Hr	heat transfer coefficient by radiation, (W/ m2. K).
L	gap between plate and cover, (mm).
$\dot{m}$	water mass flow rate, (Kg/s).

Greek Letters

τ_b	atmospheric transmittance for beam radiation.
Ɛc	emittance factor = 0.88 for glass.
Ɛp	emittance factor = 0.7 of copper.
α	absorptive.
Γ	bond average thickness.
η	solar collector efficiency
σ	boltezman Constant $= 5.67 \times 10^{-8}$.

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